A CLASSIFICATION FOR HAWAIIAN ARTIFACTS BASED ON MORPHOLOGY AND WEAR: ANALYSES OF DISCOIDAL ARTIFACTS FROM NU'ALOLO KAI, KAUA'I

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This tool [typology] is designed for the reconstruction of culture history in time and space. This is the beginning and not the end of the archaeologist's responsibility. (Ford 1954a:52).

INTRODUCTION

James Ford's decree of the purpose of typologies serves as a model for the following discussion. He believed that typologies are the products of classificatory processes – archaeologists create them in order to bound and define the variability of the empirical world. As such they are powerful tools, and their construction and use is defined by the theoretical framework that is employed to describe reality (Ford 1954a:43).

Ford's views have specific implications for Pacific archaeology. Advancements in the region over the past two decades have refined the prehistoric sequences for many islands, and understanding of the issues related to colonization and chronology (Athens and Ward 1997; Athens et al. 2002; Finney 1996; Hunt and Holsen 1991; Spriggs and Anderson 1993), subsistence (Kirch 1982; Ladefoged and Graves 2000; Moniz-Nakamura 1999; Weisler and Walter 2002), interaction (Cachola-Abad 2000; Graves et al. 2002; Kolb 1997), and emergent complexity (Cordy 1981, 1996; Hommon 1996; Sahlins 1992) have been further broadened and developed. However, in many instances the systematic analysis of artifacts has lagged substantially behind, in particular the more mundane and simple tools of daily life. This discussion focuses on the classification of relatively similar discoidal shaped artifacts from Hawai'i – gaming pieces (*'ulumaika* [bowling stones] and *kilu* [quoits]), and grinding/pounding tools (abraders and hammerstones) via a systematic classification of morphological attributes and wear patterns. The utility of a further development of this classification is demonstrated in the assessment of the diversity of *'ulumaika* morphology and material types, with particular attention paid to the performance of *'ulumaika* during play. Implications for changes in *'ulumaika* construction and increasing competition between players at different times in prehistory are considered. In addition, the analysis of wear patterns suggests multiple uses for some *'ulumaika*, and also the effects of attrition on common and uncommon materials and morphologies.

CLASSIFICATION IN ARCHAEOLOGY – THE FUNDAMENTALS

In the early decades of this century archaeologists created artifact typologies that documented the diversity of the archaeological record (Rau 1876; Wilson 1898). In later decades archaeologists established the practice of creating stylistic types of artifacts that could not only describe the archaeological record, but also construct testable chronologies and address issues of homologous similarity, human migration, and the diffusion of ideas. The work of Ford (1954a, 1954b), Gifford (1960), Kidder (1915), Krieger (1944) and especially Rouse (1939), were successful demonstrations of analytic classification. Since those early days, archaeology has expanded to include studies of cultural processes, the formation of identifies and communities, technology, and subsistence. In dealing with these complex issues, analysts have experimented with a variety of systematic and unsystematic classificatory methods, with varying rates of success and heated debates (e.g., Adams and Adams 1991; Dunnell 1978; Ford 1954a, 1954b; Gifford 1960; Haury 1950; Judd 1954; Schiffer 1992; Spaulding 1953; Taylor 1948).

Despite the diversity of theoretical perspectives and analytical techniques espoused by these scholars, the creation of typologies can be reduced to two fundamentally different classification techniques: grouping and classification. A class is an intentionally defined unit; a conceptual box created by its boundaries. More importantly, a class is a product of a classification, which in essence is a set of explicit criteria that determine the boundaries of individual classes (Adams and Adams 1991:91; Dunnell 1971:45). Systematic classifications such as paradigms and taxonomies are responsible for the generation of formal classes. A group, on the other hand, is an aggregate of events or objects that are physically or conceptually associated (Dunnell 1971:89). Grouping does not require explicit criteria that determine boundaries, and thus groups have an objective existence that is based solely on the presence of constituents. Grouping methods such as statistical clustering and numerical taxonomies are responsible for the generation of formal groups, although informal groups are also commonly employed in archaeological studies. A typology, at least in most archaeological literature, can be generated by either grouping or classification mechanisms. In most instances typologies are generated for a particular purpose, and are restricted to a particular cultural area or temporal period.

Functional Typologies and Classification in the Hawaiian Islands

The focus of classification has varied according to the goals of the discipline, and many parts in the world (such as Hawai'i) followed their own scholarly trajectories when it came to the classification of antiquities. Graves and Erkelens (1991:3) have noted that early Hawaiian typologies were the product of ethnographic, as opposed to archaeological, research. Native ethnographers such as Kamakau (1865) and Malo (1903) were essential in this endeavor, for despite the devastation of the contact period they were able to utilize genealogies, oral histories, and surviving cultural traditions to recount history and document Hawaiian culture. Early European accounts (e.g., Bates 1854; Cook 1784; Ellis 1827; Gilman 1908) also contributed additional information and observations. By the 1890's, interest in Hawaiian culture and antiquities fostered several historical treatises by non-Hawaiian scholars (e.g., Alexander 1891; Dole 1892; Fornander 1890, 1916; Jarves 1843), and in 1889 the Bernice P. Bishop Museum was established in Honolulu. In the decades to follow, museum scholars Brigham (1902, 1903, 1906), Bennett (1931), Buck (Te Rangi Hiroa) (1927, 1930, 1938, 1957), and Stokes (1927) pioneered the first archaeological studies of prehistoric Hawaiian settlements and antiquities.

Of these works, Brigham's appears to have had the most impact. In *Stone Implements and Stone Works of the Ancient Hawaiians* (1902), Brigham employed ethnographic data to group artifacts into activity clusters, which he further subdivided into functional types that were recognizable from Hawaiian culture, e.g., mortars, polishing stones, chisels, pestles, adzes, etc. Perhaps most importantly, Brigham's monograph contained vivid photographs of diagnostic artifact types, which were assembled into groups that demonstrated both the homogeneity and diversity of particular type morphologies. Although Brigham did not comment upon the methods he used to place artifacts into particular groups, careful analysis of the photographs is telling – artifacts were placed into categories based upon implicit notions of similarity. Some groups were based on morphology, and others by the location of use wear, size, or material type. In instances where artifacts were anomalous (i.e., of obscure shape or material, or unfinished), they were relegated to an "ancient" or "rude" category (Brigham 1902:43; 62).

In the following decades, excavations and cultural surveys that used Brigham's functional groups as their guide produced descriptions of subsistence and settlement patterns at both local and regional levels (e.g., Emory 1928; Buck 1957; McAllister 1933; Soehren and Kikuchi n.d.). However, new conceptions of Hawaiian prehistory emerged in the 1950s following the excavations at the Kuli'ou'ou Rockshelter. These excavations yielded deposits that were nearly 1000 years old, and contained artifacts that were unknown to Hawaiian antiquarians (Emory and Sinoto 1961). The notion that Hawai'i had a long and complex history served as a catalyst for the revision of the existing artifact typology. Most notably, Emory, Bonk and Sinoto (1959) and later Sinoto (1962) recognized that the stylistic traits inherent in fishhooks could indicate temporal change and interaction. Their research demonstrated that the variability in artifact form, which in previous decades had been ignored or thought to be uninformative, could yield data that was crucial to prehistoric research

Sinoto et al.'s findings opened the door for more intensive and explicit classifications of Hawaiian (and other east Polynesian) material culture. Archaeology performed in the 1960s and 70s retained the functional groupings established by Brigham, and added additional analyses of morphology and wear to produce a typology that included regional and temporal variants (e. g., Kirch 1985; Kirch and Kelly 1975; Pearson, et al. 1971; Soehren and Tuohy 1987). Artifacts with diverse morphologies were investigated in more detail, as their variability could potentially address complex issues of chronology, interaction, exchange, and competition. Fishhooks (Allen 1992, 1996; Moniz-Nakamura et al. n.d.) and adzes (Cleghorn 1982; Emory 1968; Lass 1994) are the most diverse in form of the portable artifacts, and have received the most attention. Evolutionary informed studies of octopus lure weights (Pfeffer 1995), poi pounders (McElroy 2003), and ceremonial architecture (Cochrane 1998, 2002; Graves and Cachola-Abad 1996) have also made substantial contributions to current understandings of Hawaiian and east Polynesian prehistory. However, more mundane artifacts, such as hammerstones, abraders, files, chisels, and other implements have been studied to a much lesser extent. Recent analyses have demonstrated potential avenues of research for such artifacts, which often go overlooked, yet contain vital information pertaining to subsistence and technology. For example, McElroy's study of basalt and coral files (McElroy 2000) indicates a variety of behavioral and cultural traits related to the selection and use of different materials during fishhook manufacture. Studies of this kind that also utilize temporally indexed collections have the potential to delineate technological trends, which differentially spread and persisted throughout Hawaiian prehistory. Perhaps just as important, explicit classifications that focus on the variability of artifact morphology, wear patterns, and performance can potentially alleviate identification problems associated with the traditional Hawaiian artifact typology (e.g., Brigham 1902). Rather than implicit categorization based upon artifact morphology or material type (e.g., "pounders", "grinders", "abraders" etc.), artifacts can be classified accorded to the presence of wear and morphology that is indicative of variations in use. At present, archaeological protocols in Hawai'i encourage some advanced levels of artifact analysis, however, more intensive studies would be an important addition to Hawaiian archaeology, as the complete identification of activities would provide a much fuller picture of ancient subsistence and settlement behaviors.

A Classification of Morphology and Wear

The classification of some of the least complex artifacts in Hawaiian archaeology requires a unique approach. Shepard (1956), Dunnell and Lewarch (1974), Dunnell and Campbell (1977), Campbell (1981), and Allen (1992) made steps in this direction when they developed some of the first classifications of artifact morphology and wear. In simple terms, artifact morphology is the result of either manufacture or attrition, and its documentation requires the creation of a classification that can record the variability of a 3-dimensional object. The simplest classification of morphology requires the dimensioning of an artifact into plan view, side view, and end view (X, Y, and Z faces)[1]. Each face can then be classified according to its congruence with one of a selection of morphological classes, the shape of which are determined by the co-occurrence of three variables: the number of sides, the presence/absence and frequency of interior and exterior angles, and the number of planes of symmetry[2]. According to Euclidean geometry the co-occurrence of these variables generates roughly 40 combinations, which manifest as a variety of symmetrical and non-symmetrical polygons. These include triangles, quadrilaterals, pentagons, hexagons, octagons, and dodecagons (circles). Irregular shapes generated by the presence of exterior angles are also included amongst the possible morphological classes. Classification itself can be performed via visual inspection or with digital photographs that are later analyzed with drafting software such as SigmaScan or Canvas. Each artifact can thus be summarized as a series of six classes, each of which describes the morphology of plan, side, and end view.

In addition to morphology, wear is directly indicative of both the manufacturing techniques and uses of a particular object. More specifically, wear is the direct result of human articulation with the environment, and it can occur on an artifact in a variety of forms (i.e., crushing, abrasion, chipping), and across many surfaces. This being the case, the actual instances of wear, not the object itself, are the focus of the classification. Allen (1992:204) designed a wear classification that is based upon the intersection of five dimensions: kind of wear, location of wear, edge angle, shape of wear, and orientation. Within this system, artifacts are visually examined for the presence of chipping, crushing, abrasion, and polishing, and then further classified according to the location of the wear on the artifact, the shape of the worn surface, and the orientation of the wear on the artifact. As with the morphological classification, each artifact can be summarized as a series of five wear classes, although in some cases an artifact will be classified several times due to the presence of multiple instances of wear on either the sides, tips, or other surfaces of an artifact. A classification of this kind is advantageous in that it makes possible an evaluation of the entire range of functional activities in which an object may have participated.

The proposed classification of wear and morphology is paradigmatic in structure (i.e., dimensional, with mutually exclusive modes), which is the most efficient system for dealing with the complex variables involved in artifact morphology and use. The large body of information that is generated for each object is of value, as simple analyses can determine assemblage-wide trends in artifact manufacture and use. Allen (1996) and Moniz-Nakamura et al. (n.d.) established that traits that cooccur on more than one kind of material are more likely to be stylistic, i.e., the trait does not affect the performance of the item, and its presence indicates design choices made during manufacture. In addition, traits (e.g., specific morphological combinations) that occur in one material type but not in others may be related to functional differences. Wear studies can indicate how these artifacts may have been used differently if their material varied, and if there were preferences for one material over another. In some cases, the co-occurrence of certain classes will be indicative of the differentiation between artifact design and function. For example, two basalt artifacts that share identical use wear patterns but contrast in only one dimension of morphology may be functionally identical but stylistically different (e.g., cutting tools that differ in the shape of their cross-section). In this case, the variation exhibited by the class may be indicative of cultural preferences for certain designs. In other cases, artifacts may be identical in morphology but differ in patterns of use wear, thus indicating difference in use, e.g., plummet-shaped fishing weights and conical pounding tools.

DISCOIDAL ARTIFACTS IN HAWAI'I

Nu'alolo Kai (KA-C10-2) was an ancient Hawaiian settlement located on the remote Na Pali coast of Kaua'i (Figure 1). Excavations were conducted at the site by Bishop Museum archaeologists Emory, Soehren, and Kikuchi between 1958 and 1964, and the deep deposits yielded some of the rarest cultural remains in all of Hawai'i, including feathers, *kapa*, gourds, and a rich variety of wood, stone, shell, and bone implements. Chronological analyses by Soehren and Kikuchi (n.d.) and later by Moniz-Nakamura et al. (n.d.) indicate that the site was occupied as early as A. D. 1100, and was maintained as a remote settlement until the 1800s. Although of small size, the village contained several occupational components, including houses, canoe sheds, a *heiau* (religious structure), and a large system of *lo'i* (irrigated *kalo* ponds) in a nearby valley. The collection of artifacts recovered from the site was partially analyzed by Bishop Museum archaeologists in the 1970s (Soehren and Kikuchi n.d.), although in recent years the collection has undergone reanalysis with the morphological and use-wear classification described above. As an example of the utility of the classification, the following discussion will describe the analysis of discoidal artifacts from Nu'alolo Kai. Under the traditional functional typology, discoid-shaped artifacts were grouped under categories of gaming stones or grinding/pounding tools, i.e., *'ulumaika*, *konane* stones, *kilu*, hammerstones, and abraders. Although these artifacts were functionally distinct their basic morphology was quite similar— hence the common conflation of these artifacts (Figure 2). The following sets of analyses classify an assemblage of discoidal artifacts according to morphology and wear. In so doing, the actual function(s) of these objects can be ascertained.

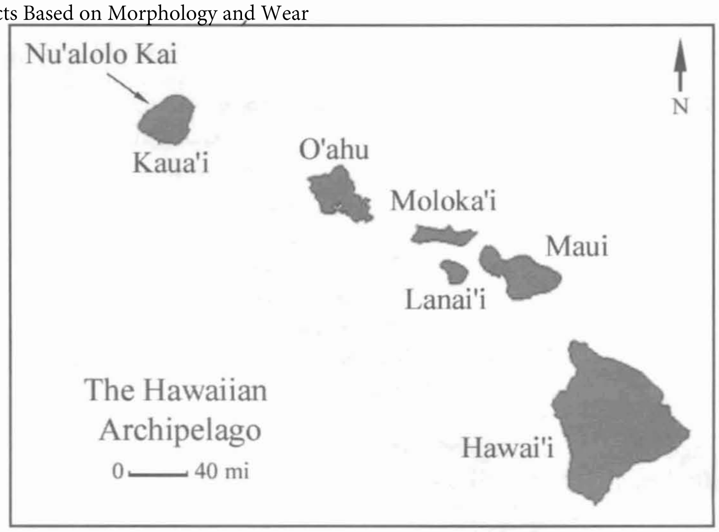

Figure 1. Location of the site of Nu'alolo Kai (KA-C10-2), located along the Na Pali coast of Kaua'i.

Discerning Manufacture from Attrition

The morphological classification was applied to 2730 artifacts in the Nu'alolo Kai collection. Queries within the database identified artifacts that were round in plan view and either rectangular, or elliptical in side view. This resulted in an assemblage of 26 artifacts that were made of coral, basalt, limestone, hematite, and coquina. Coquina is essentially reef detritus (broken shells and coral sand) that has cemented together to form a conglomerate. In addition, a query was used to identify artifacts that were round in plan view and only partially symmetrical in side view, thus adding an additional three artifacts that were somewhat irregular in form. In their initial typology of

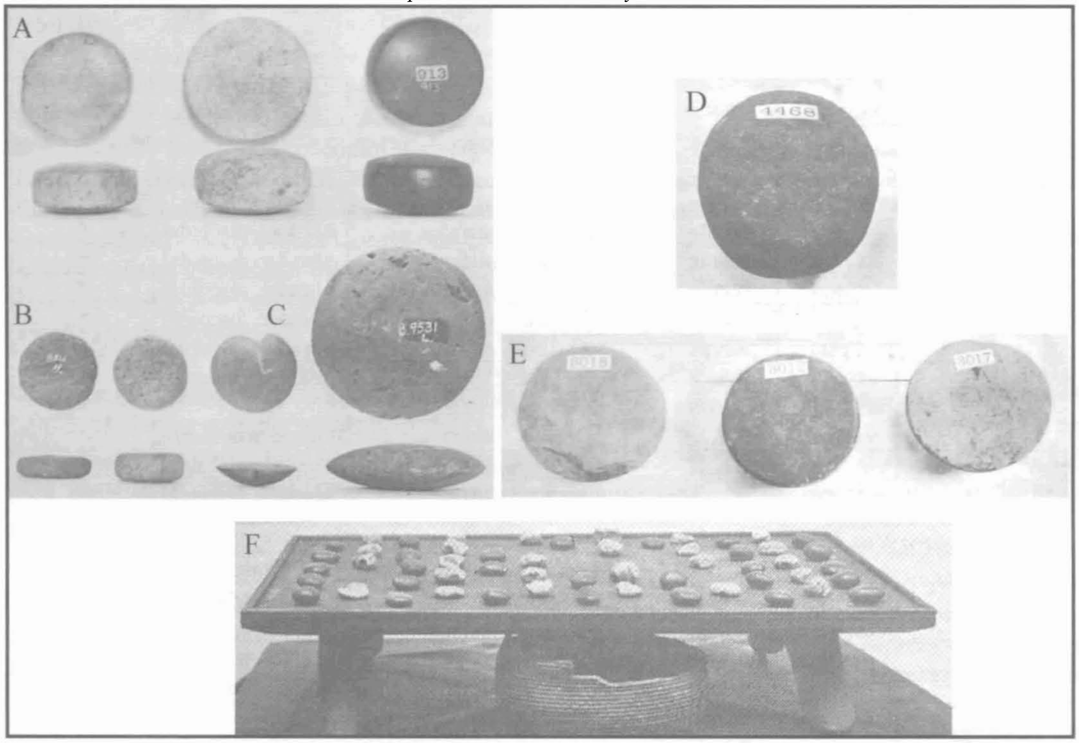

Figure 2. Discoidal artifacts from Hawai'i. A) Biconvex *'ulumaika*; B) Flat-Sided *'ulumaika*; C) *kilu* (Buck 1957:372). D) hammerstone (Brigham 1902:338); E) polishing stone (disc abrader) (Brigham 1902:plate XXXV);

shaped and smoothed wooden canoes or other objects.

In other circumstances it is more difficult to discern manufacture from attrition. Four basalt artifacts in the Nu'alolo Kai collection are particularly demonstrative of this problem. Traditionally, hammerstones and *'ulumaika* were differentiated by shape and material type, as it was assumed that most pounding tools would be spherical and composed of dense basalt, and most *'ulumaika* would be well-formed discoids. However, the use of vesicular basalt for pounding was not uncommon, and there was always the potential for broken *'ulumaika* to be re-used as hammerstones. A classification that can focus on the finer morphologies and wear patterns of artifacts such as these has the potential to accurately discern the range of activities these artifacts represent. For example, two artifacts were classified as discoidal hammerstones according to the functional typology. Both were made of vesicular basalt and crushed across all surfaces. However, one of was crushed more extensively, to the point that it was nearly spherical in shape (# 433), while the other retained flatter sides and a more ovoid cross section (# 432). The presence of crushing across all surfaces is more suggestive of pounding activities, thus artifact # 433 was most likely used as a hammerstone. However, the flat-sided morphology of # 432 is more suggestive of an *'ulumaika*. In comparison, two artifacts appear to have been originally manufactured as *'ulumaika*, but were later re-used as hammerstones. Artifact # 669, which was classified as a "basalt disc" under the functional typology, is one such artifact. This object was crushed and abraded into a distinct discoid shape, but also shows evidence of extensive battering and wear along the sides and edges. Similarly, artifact # 284 was categorized by the functional typology as an *'ulumaika*, but also demonstrates extensive wear that is indicative of its subsequent use as a pounding tool.

the Nu'alolo Kai artifacts, Soehren and Kikuchi (n.d.) noted that it was difficult to classify discoidal artifacts due to the overlapping definitions for abraders, *'ulumaika*, and hammerstones. In their final analysis, eight of these artifacts were designated as discoid-shaped abraders, two were discoidal hammerstones, fifteen were *'ulumaika*, and one artifact each was designated as a stone disc, *'ulumaika*/hammerstone, *konane* stone, and a quoit (Table 1). The analysis and classification of material types, morphology, and wear presented herein suggests that in some cases, the discoid-shaped artifacts in the sample were used for other or multiple purposes than originally specified by Soehren and Kikuchi. The analysis also demonstrates how morphology and wear can be used to determine function and morphological variation as it relates to attrition and choices made during manufacture.

For example, of the eight artifacts that were classified as discoidal abraders under the functional typology, seven were composed of coral (*Porites lobata*) and exhibited extensive abrasion and crushing wear on their surfaces (#s 320, 321, 322, 323, 326, 327, 517). The eighth artifact (# 450) was composed of vesicular basalt, and was abraded and crushed more extensively in one direction, thus producing an asymmetrical cross section (Y face). The wear patterns and morphologies of these artifacts all suggest tools that were used for grinding or sanding softer materials (such as wood), although the difference in material types (basalt vs. coral) may reflect the need for rougher grinding surfaces in some tasks. However, the morphologies of the artifacts are all due to attrition, both natural and man-made. Most likely, these artifacts originated as water-worn beach cobbles, which were subsequently ground into discoids as they

Advanced Morphological/Wear Classification – Gaming Stones

Within the Nu'alolo Kai collection, the most congruence between Soehren and Kikuchi's functional typology and the morphological/wear classification was with artifacts that were used in games and competitions. Ethnographic and historic literature from Hawai'i records several games, including *pā'ani* (team sports) and *mokomoko* (individual sports and games). These games were played throughout the year, but with more

Table 1. Discoidal artifacts from the Nu'alolo Kai collection.

Artifact ID#	Class 1[1]	Subclass	Class 2[2]	Material Type	Portion	Condition/Location of Wear[3]	Soehren et al. type[4]	*`Ulumaika* Morph. Class
282	*Konane* Stone	*	*	Aph. Basalt	Whole	Polished, surfaces	Konane Stone	*
320	Abrader	Discoidal	*	Coral	Whole	Abraded, surfaces	Abrader, discoidal	*
321	Abrader	Discoidal	*	Coral	Whole	Crushed, surfaces	Abrader, discoidal	*
322	Abrader	Discoidal	*	Coral	Whole	Abraded, surfaces	Abrader, discoidal	*
323	Abrader	Discoidal	*	Coral	Whole	Abraded, surfaces	Abrader, discoidal	*
326	Abrader	Discoidal	*	Coral	Whole	Abraded, surfaces	Abrader, discoidal	*
327	Abrader	Discoidal	*	Coral	Whole	Abraded, 2 surfaces	Abrader, discoidal	*
380	*Kilu*	*	*	Hematite	Fragment	Chipped, edge	Quoit?	*
433	Hammerstone	*	*	Ves. Basalt	Whole	Crushed, surfaces	Hammerstone, disc.	*
450	Abrader	Discoidal	*	Ves. Basalt	Whole	Abrad., crushed, surfaces	Abrader, discoidal	*
517	Abrader	Discoidal	*	Coral	Whole	Abraded, surfaces	Abrader, discoidal	*
284	*`Ulumaika*	*	Hammerstone	Ves. Basalt	Whole	Crushed, edges	*`Ulumaika*	222
285	*`Ulumaika*	*	*	Aph. Basalt	Fragment	Abrad., crushed, edges/surface	*`Ulumaika*	242
286	*`Ulumaika*	*	*	Ves. Basalt	Whole	Crushed, surfaces	*`Ulumaika*/hammer	222
287	*`Ulumaika*	*	*	Ves. Basalt	Whole	Crushed, surfaces	*`Ulumaika*	222
288	*`Ulumaika*	*	*	Ves. Basalt	Whole	Abrad., chipped, edges/surface	*`Ulumaika*	222
289	*`Ulumaika*	*	*	Ves. Basalt	Whole	Crushed, surfaces	*`Ulumaika*	222
290	*`Ulumaika*	*	*	Ves. Basalt	Whole	Crushed, surfaces	*`Ulumaika*	222
363	*`Ulumaika*	*	*	Coral	Whole	Abraded, surfaces	*`Ulumaika*	222
364	*`Ulumaika*	*	*	Hematite	Whole	Unworn	*`Ulumaika*	222
365	*`Ulumaika*	*	*	Coquina	Whole	Crushed, surfaces	*`Ulumaika*	222
366	*`Ulumaika*	*	*	Coquina	Whole	Crushed, surfaces	*`Ulumaika*	332
367	*`Ulumaika*	*	*	Limestone	Fragment	Unworn	*`Ulumaika*	242
368	*`Ulumaika*	*	Hammerstone	Limestone	Fragment	Chipped, crushed, edges	*`Ulumaika*	442
369	*`Ulumaika*	*	*	Limestone	Fragment	Chipped, edges	*`Ulumaika*	242
370	*`Ulumaika*	*	*	Limestone	Fragment	Chipped, edges	*`Ulumaika*	222
371	*`Ulumaika*	*	*	Coquina	Whole	Chipped, surfaces	*`Ulumaika*	222
372	*`Ulumaika*	*	*	Limestone	Whole	Unworn	*`Ulumaika*	222
373	*`Ulumaika*	*	Hammerstone	Limestone	Fragment	Crushed, surfaces	*`Ulumaika*	222
375	*`Ulumaika*	*	*	Limestone	Fragment	Fractured	*`Ulumaika*	200
376	*`Ulumaika*	*	*	Limestone	Fragment	Fractured	*`Ulumaika*	200
377	*`Ulumaika*	*	*	Limestone	Fragment	Fractured	*`Ulumaika*	200
378	*`Ulumaika*	*	*	Limestone	Fragment	Fractured	*`Ulumaika*	200
379	*`Ulumaika*	*	*	Limestone	Fragment	Fractured	*`Ulumaika*	200
381	*`Ulumaika*	*	*	Coquina	Fragment	Fractured	*`Ulumaika* fragment	222
382	*`Ulumaika*	*	*	Coquina	Fragment	Abraded, surfaces	*`Ulumaika* fragment	200
391	*`Ulumaika*	*	*	Aph. Basalt	Fragment	Fractured	Adze chip	200
432	*`Ulumaika*	*	*	Ves. Basalt	Whole	Crushed, surfaces	Hammerstone, disc.	222
448	*`Ulumaika*	*	*	Ves. Basalt	Whole	Crushed, surfaces	*`Ulumaika*	222
451	*`Ulumaika*	*	*	Ves. Basalt	Whole	Crushed, surfaces	*`Ulumaika*	222
619	*`Ulumaika*	*	*	Coquina	Whole	Crushed, surfaces	*`Ulumaika*	332
633	*`Ulumaika*	*	*	Limestone	Fragment	Fractured	*`Ulumaika*	222
636	*`Ulumaika*	*	*	Limestone	Fragment	Fractured	*`Ulumaika*	222
668	*`Ulumaika*	*	*	Ves. Basalt	Whole	Crushed, surfaces	*`Ulumaika*	332
669	*`Ulumaika*	*	Hammerstone	Ves. Basalt	Whole	Abrad., crushed, surfaces	Basalt disc	222
822	*`Ulumaika*	*	*	Limestone	Fragment	Fractured	*`Ulumaika*	222
823	*`Ulumaika*	*	*	Limestone	Fragment	Fractured	*`Ulumaika*	200
824	*`Ulumaika*	*	*	Coquina	Fragment	Abraded, surfaces	*`Ulumaika*	200
1831	*`Ulumaika*	*	*	Hematite	Fragment	Abraded edge, surfaces	Hematite	200

[1]Class 1 indicates the primary functional designation for an artifact. Class 1 is determined by the analysis of morphology and wear patterns on an object, and also by comparison to traditional artifact typologies for the Hawaiian Islands.
[2]Class 2 indicates the secondary functional designation for an artifact, which is determined in the same manner as Class 1.
[3] The kind and extent of wear recorded for each artifact utilized the wear classification outlined by Allen (1992:204). The data presented in this column is a summary of the five (or more) dimensions of wear that were recorded for each artifact.
[4] The types indicated in this column were designated by Soehren et al. (n.d.) between 1958-66.

intensity and competition during the *Makahiki* season (late fall and winter). Games included *kuikui* (boxing), *'uma* (hand wrestling), *kukini* (foot racing), *hukihuki* (tug-o-war), *he'e nalu* (surfing), *he'e pahe'e* (javelin throwing), *mo'a pahe'e* (javelin sliding), *he'e hōlua* (track sledding), *hu* (spinning tops), *konane* (checkers), *kilu* (pitching discs), and *maika* (track bowling). Of these sports and games, only the last five are detectable in the archaeological record. *Hōlua* sledding involved the construction of stone tracks and ramps, many of which have been preserved in some of the remoter parts of Hawai'i (Stone and McAnany 1997). *Hu* (spinning tops), were most likely constructed for and used by children. Although rare, these pecked coral toys have also been recovered from habitation sites (Soehren and Tuohy 1987). *Konane*, a game similar to European checkers, was played upon a wooden board (*papamu*) or pecked stone surface. The game used coral and basalt pebbles (*'ili kea*, *'ili 'ele*) for "men", some of which turn up in archaeological sites. A small basalt pebble from the Nu'alolo Kai collection (# 282) may have been part of a *konane* game. *Kilu* (pitching discs, or quoits) are exceptionally rare, and are virtually unknown to ethnographic or historical literature. Bishop (1940) and Emory (1965) have suggested that game involved spinning or flinging the *kilu* disc towards a pole, and by striking the pole the player would receive a point. A lens-shaped hematite artifact was recovered from the deposits of Nu'alolo Kai, (# 380) and it has been tentatively identified as a *kilu*, due to its highly polished surface and lack of edge wear.

In comparison, the game of *maika* was commonly played throughout Hawai'i, and stones used in the game have been found in archaeological sites dating back to the 8th century AD (Kirch and Kelly 1975). Other versions of the game are known from Samoa and the Cook Islands, and most likely the more ancient aspects of the game originated amongst these islands. In Hawai'i, *maika* was an adult game, and the stones used for playing (*'ulumaika*) were manufactured to be swift, balanced, and durable. Variability in the way the game was played is suggested through oral historical data, and the vast array of materials used to create *'ulumaika*. Morphology and wear patterns on the stones themselves also suggest that the game had several variations, which may represent regional or temporal trends in game playing or competitions.

In broad terms, the game was similar to European bowling, and Malo suggests the game involved a great deal of competition and betting. The principle point was to send a discoid-shaped object (the *'ulumaika*) down a prepared track (the *kahua*) as far as was possible. Several players could be involved in the game, and whoever had the longest throw was declared the winner. In his translation of Malo, Emerson noted that additional trials in the *maika* game incorporated accuracy, in the form of two stakes set up some distance from the start of the course, and separated by only a few inches. Players would attempt to roll their *maika* stones between those stakes to win the event. (Malo 1951:221). There is also documentation that suggest that a few *kahua maika* on Moloka'i (Kaunakakai and Lanikaula) were constructed to include a curve, and *'ulumaika* of those competitions were manufactured to roll in a curving trajectory (Malo 1951:221). Brigham described a third trial in the game that involved rolling the *maika* stones against one another, and the most durable stones would be proclaimed the winner. At the turn of the century when Brigham was writing, a famous *kahua maika* on Moloka'i was reputed to be littered with "hundreds of *ulu* [*maika*] so broken that the fragments were not worth carrying off" (Brigham 1902:400).

These variations in the game suggest that players may have experimented with a variety of *'ulumaika* morphologies and material types, in order to create stones that could roll in either straight or curved trajectories, and perhaps in some cases be durable enough to withstand collisions. Malo describes the *maika* stone as "fashioned after the shape of a wheel, thick at the center and narrow at the circumference – a biconvex disc" (Malo 1951:220). Brigham noted this as well, but also added that some *'ulumaika* had flattened rather than convex sides (Brigham 1902:401). Malo and Brigham also described the *'ulumaika* as being "of various sizes, being all the way from two and a quarter to six inches in diameter", and "made from many varieties of stone, and they were accordingly designed after the variety of stone from which they were made" (Malo 1951:220-221). Although it is difficult to ascertain from Malo and Brigham how *'ulumaika* morphology was related to performance in the game (either rolling or colliding), they do indicate that morphology was in some way dictated by material type. This suggests that some degree of artifact morphology was predetermined by qualities of the material, and that the manufacturers of *'ulumaika* may have selected both material and morphologies with specific performance goals in mind. The analysis of material types, wear patterns, and morphologies amongst a sample of *'ulumaika* may provide additional insights into how the game was played, and perhaps how it changed over time to emphasize different aspects of *'ulumaika* performance. These analyses also suggest that some *'ulumaika* were expedient tools, i.e., they were hastily made, and others were the products of master craftsmen. Broken or worn out *'ulumaika* were also used for a variety of other activities, as evidenced by their wear patterns.

MATERIAL TYPES, MORPHOLOGY, AND WEAR AMONGST HAWAIIAN *'ULUMAIKA*

As before, a paradigmatic classification was employed to explicitly classify morphological features and instances of wear. Previous analyses identified artifacts that were round in plan view and either elliptical or rectangular in side view. Excluding the artifacts that had instances of wear and morphologies indicative of their use as abraders, hammerstones, *kilu*, or *konane* stones, 18 whole *'ulumaika* were classified from the Nu'alolo Kai collection. Initial classification of wear suggested that most *'ulumaika* had abraded or polished convex surfaces, so an additional query was performed to assemble artifacts that were potentially the fragments of broken *'ulumaika*. This resulted in a total assemblage of 38 broken and whole artifacts. A secondary classification was employed to further classify the morphology of *'ulumaika*. This system classified artifacts according to the presence of convex, concave, flat, or indeterminate surfaces on the Y^1, Y^2, and X sides (Table 2), and generated 125 potential classes, 6 of which occurred within the sample.

Material Type vs. 'Ulumaika morphology

Twenty one (55%) of the *'ulumaika* were classified as

Table 2. Classification of *'ulumaika* based upon the morphology of the Y^1, Y^2, and X surfaces. 125 potential class combinations are generated by this classification.

I. SURFACE OF Y^1
0. surface lacking*
1. concave surface
2. convex surface
3. flat surface
4. indeterminate surface

II. SURFACE OF Y^2
0. surface lacking*
1. concave surface
2. convex surface
3. flat surface
4. indeterminate surface

III. SURFACE OF *X*
0. surface lacking*
1. concave surface
2. convex surface
3. flat surface
4. indeterminate surface

The Classes filled by Nu'alolo Kai collection: 222, 242, 220, 200, 332, 442.

*In instances where two surfaces are perfectly convex, their intersections do not permit the formation of a distinct Y^1, Y^2, or *X* plane.

class 222; artifacts with convex surfaces on the Y^1, Y^2, and X faces (Table 1). This is the classic biconvex disc shape that both Malo and Brigham described. However, if the fragmentary *'ulumaika* with convex Y faces are also included (classes 242, 220, 200), a total of 34 (89%) of the artifacts in the Nu'alolo Kai collection consist of biconvex *'ulumaika.* Only three specimens were members of class 332 – *'ulumaika* with flat sides and convex rolling tracks. Concave-sided *'ulumaika* were not present, although they have been recorded from other parts of Hawai'i (McAllister 1933:50). An additional specimen was of poor condition and mostly indeterminate in morphology (class 442). Of note, class 222 occurs across all material types, including basalt (both vesicular and aphanitic), coral, coquina, limestone, and hematite. This diversity is particularly interesting, as coquina is very crumbly and limestone and hematite are quite brittle. This pan-material distribution suggests that the biconvex morphology was a choice selected by the manufacturers, and not pre-determined by the qualities inherent in the raw material (cf. Malo 1951). It may also suggest that the color of the raw material, and its ability to be worked to a high polish, may have been more important to manufacturers than simple durability.

However, Allen (1996) has suggested that traits that co-occur on more than one kind of material indicate design choices that do not affect performance (i.e., the traits are stylistic). This may not have been the case for Hawaiian *'ulumaika.* Emerson suggests that the game of *maika* originally employed unripe breadfruit (*ulu*), which were gradually replaced with spherical stones as the centuries progressed (Emerson, in Malo 1951:221). If Emerson is correct, the manufacture of biconvex discs in later centuries may represent the further evolution of the game. Most likely this transition occurred throughout Polynesia, as biconvex discs are also the predominant form in *maika*-like games in Samoa and the Cook Islands. Notably, the version of the game played in the Cook Islands employed wooden biconvex discs and a throwing sling made of hibiscus bark, which was wrapped around the flat 'track' of the disk and then used to fling the disc down a prepared lane (Buck 1927:341).

Although it is unknown if the use of fiber slings was prevalent at any time in other parts of Polynesia, the design may have been part of a trend towards increased acceleration and accuracy. This is suggested to some extent by physics, within which the properties involved in the rotation of solid bodies are well understood. Physics dictates that the rotational inertia of solid spheres is less than that of discs, thus round and disc-shaped gaming stones would not have performed equally in distance competitions. In controlled experiments, spheres accelerate more easily than cylinders or discs, because as an object's mass is moved away from its axis of rotation, the object's rotational inertia increases[3]. However, the use of a sling would have dramatically improved the acceleration of any gaming stone, surpassing even a sphere that was thrown by hand. If the early development of the *maika* game involved the use of fiber slings, this may explain why players preferred to manufacture discoid gaming stones, as opposed to spherical ones, throughout the later periods of east Polynesia. In conparison, biconvex *'ulumaika* may have developed as an efficient hybrid of disc and spherical morphologies; the flattened sides perhaps made throwing easier, and the rounded shape would have allowed quick acceleration and long distances that were almost equivalent to that of sphere-shaped objects. In addition, biconvex discs may have been favored for their stability, as the equal curvature of the sides may have helped to keep the stone balanced. Experimental tests performed by the author involving ceramic *'ulumaika* indicate that the flat-sided discs were considerably less stable, and had slower rates of acceleration.

These findings suggest that the biconvex morphology that is common in Hawaiian *'ulumaika* is most likely related to the performance of the object, as opposed to a purely stylistic choice made by the manufacturer. This shape is perhaps due to evolutionary developments in the playing of the *maika* game, in which early players shifted to forms that were perhaps easier to throw, but which maintained the speed, accuracy, and balance needed for performance. The existence of flat-sided variants in Hawaiian *'ulumaika* may suggest later experimentation, the use of expedient materials, or perhaps the slow attrition of stones during many instances of play. The following discussion will focus on the wear patterns inherent in all the *'ulumaika* forms, which may indicate variances in *'ulumaika* manufacture, use, and subsequent modification.

'Ulumaika Morphology and Attrition-Related Wear

Of the 34 biconvex *'ulumaika*, the most common material type was limestone (15, or 44%). This material was probably favored for its creamy white color and its ability to be worked to a high polish. However, the fragility of limestone is evident from the Nu'alolo Kai collection, which contains only one complete limestone *'ulumaika.* As a group limestone *'ulumaika* are heavily fractured, and most likely this wear pattern is due to their breakage during play – either in collision with the surface of the *kahua*, or in collisions with other *'ulumaika*. Two limestone *'ulumaika* (# 368, 373) are also chipped and crushed along their fractured edges, which suggests that these artifacts were used for cutting or chopping at a later time. Small *'ulumaika* flakes that had sharp edges may have also been curated as expedient cutting tools.

Twelve (35%) of the biconvex *'ulumaika* are composed of basalt, which includes both aphanitic and vesicular varieties. Basalt was the preferred material for *'ulumaika* throughout Hawai'i, as it could be pecked and crushed into almost any shape, and was exceptionally durable. Wear patterns on the Nu'alolo Kai *'ulumaika* indicate extensive play – all of the vesicular basalt *'ulumaika* are complete, yet they show crushing wear on their rolling surfaces. Three specimens also have instances of chipping and abrasion along their edges, two of which (# 284, 669) are severe enough to suggest that they were used as expedient hammerstones. The two aphanitic basalt *'ulumaika* (# 285, 391) are both fragmented from play, but only one has chipped and abraded edges that indicate extensive rolling. Neither of these artifacts appears to have been subsequently used for pounding or grinding. In addition, a single vesicular basalt *'ulumaika* (# 668) was classified as a member of class 332 – the flat sided morphology This artifact has wear patterns that were similar to biconvex *'ulumaika* of the same material, and is otherwise unremarkable.

The iconoclasts of the Nu'alolo Kai collection are the coquina *'ulumaika,* as these artifacts show the most diversity in morphology and wear patterns. Coquina particles are generally large and its consistency crumbly, although it can be easily pecked into any shape desired. However, compared to basalt and coral, it is not a very efficient material for either grinding or pounding. Its occurrence as an *'ulumaika* material type suggests that these were expedient game stones, and not made to the standard of traditional *'ulumaika.* This being the case, these artifacts reflect both morphologies: biconvex (# 365, 371, 381) and flat-sided (# 366, 619). Moreover, the effects of attrition are also evident in the classification of the morphology of coquina *'ulumaika*. Two of the seven are fragmented, and nearly all exhibit crushing and abrasion on their sides and rolling surfaces. It is also possible that the occurrence of the flat-sided morphology is due to the weathering of the parent material.

Lastly, the most rare material types amongst the Nu'alolo Kai *'ulumaika* were those composed of hematite and coral. Only two hematite specimens were recovered. Both were of the biconvex disc morphology and had polished surfaces that brought out their deep red color. The whole specimen (# 364) was in excellent condition, and may not have been used extensively as it lacked extensive edge or surface chipping. The other hematite *'ulumaika* was a fragment (# 1831), which appeared to have been slightly abraded. This may suggest that after breakage the fragments of the hematite were used for creating red pigment. The single coral *'ulumaika* (#363) was also in the shape of a biconvex disc. This artifact is extraordinarily symmetrical, which suggests the work of a master craftsman. This *'ulumaika* also shows little wear related to game playing, and may not have seen much use.

Discussion

The classification of morphological variation amongst a sample of Hawaiian *'ulumaika* indicates that in most circumstances, gaming stones were made by accomplished craftsmen who preferred biconvex morphologies to flat-sided or irregular morphologies. Historical and ethnographic analyses suggest that this form derived from an earlier spherical morphology, and the retention of partial sphericity in the biconvex form was perhaps due to player preference – it would have retained the speed and accuracy of the more ancient spheres, yet out-performed flat-sided variants. The occurrence of the biconvex morphology across material types is also indicative of the functional superiority of this design. Although limestone and hematite were less durable, the use of these materials indicates that the color (and potential for a high polish) was also preferable to the more mundane basalt. Figure 3 plots the distribution of the 38 *'ulumaika* in the Nu'alolo Kai collection according to morphology, material type, and temporal periods established by Moniz-Nakamura et al. (n.d.). Despite the small sample size, trends in manufacture are evident. The classic biconvex form is the most common in all periods, although the flat-sided variant occurs in low numbers between AD 1450 and the

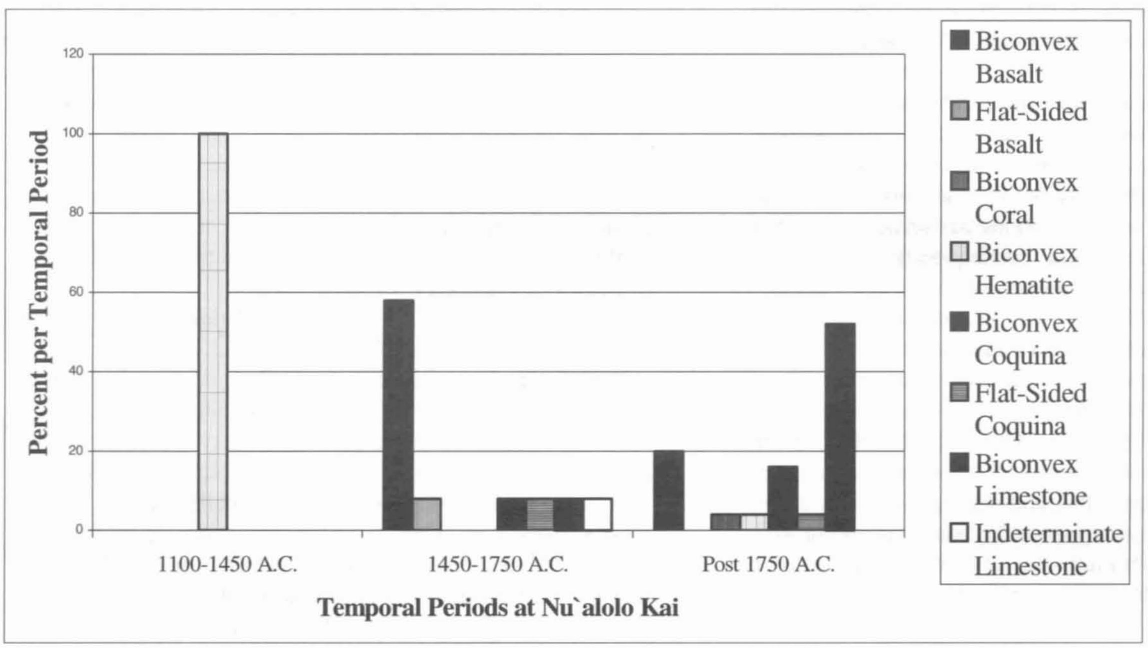

Figure 3. The distribution of *'ulumaika* according to morphology and material type throughout the prehistoric sequence of Nu'alolo Kai.

contact period. Basalt is the most prevalent material type between AD 1450-1750, and although it remains common in the latest temporal period, other material types such as limestone and coquina increase in frequency after AD 1750 These data suggest that diversity in *'ulumaika* form and material type was present as early as the 12th or 13th century at Nu'alolo Kai (the earliest *'ulumaika* is actually composed of hematite), and during the period of AD 1550-1750, the materials from which *'ulumaika* were made became increasingly variable.

It is not possible to discern whether the *'ulumaika* of Nu'alolo Kai participated in the collision variation of the game that is recorded for Moloka'i. Brigham's description of *kahua maika* on Moloka'i suggests that these were made from basalt *'ulumaika* (most likely fine-grained, as this region is known for having several adze quarries) that had been broken during play. The Nu'alolo Kai collection also contained two aphanitic basalt *'ulumaika*, both of which are fragmented. However, the bulk of the basalt artifacts were of the vesicular variety, and unbroken. Thus, it is difficult to determine whether the fragmentation of limestone and aphanitic *'ulumaika* (and conversely, the soundness of vesicular basalt) is a result of intentional collisions, or the brittle/durable nature of these materials. Additional studies of *'ulumaika* from other sites, particularly the *kahua maika* of Kaunakakai and Lanikaula, may aid in determining the extent to which variations in the *maika* game existed in prehistoric Hawai'i. What is certain is that at the remote village of Nu'alolo Kai, *'ulumaika* were expediently made of less than optimal materials (coquina), in the later periods, although better materials and finely crafted *'ulumaika* were available. This may suggest play by children, or perhaps practicing with 'junk' *'ulumaika* by adults (i.e., Brigham 1902:401). Throughout the sequence, whole and broken *'ulumaika* were re-used as pounding, cutting, and chopping tools.

CONCLUSION

The morphological and wear classifications presented in this study allow for systematic analyses of discoidal artifacts from the Na Pali coast of Kaua'i. More specifically, this classification identifies patterns of use-wear amongst morphologically similar objects, and discerns distinct activities associated with grinding, pounding, and game playing. In addition, this classification was further used to identify variations within the game of *maika*, including the way in which gaming stones performed, how they were manufactured and used, and consequently recycled as other tools. This study demonstrates the utility of a systematic classification for artifacts that normally receive little attention. Research such as this in Hawai'i (and other parts of the Pacific) has been largely overshadowed by multi-disciplinary studies of settlement patterns and subsistence, and the regular use of radiometric dating for chronology (e.g., Dixon et al. 2002). Without doubt, these studies have developed scholarly conceptions of Hawaiian prehistory to an advanced degree. It is contended herein that more advanced analyses and classifications of artifacts in tandem with these broader studies can provide a more comprehensive account of Hawaiian prehistory.

NOTES

[1] The orientation of artifacts in the *X*, *Y*, and *Z* dimensions is an arbitrary construction, but for consistency in classification it is necessary to follow these simple rules:

The Y axis: the longest extension of the artifact (the longest side) determines the positioning of the *Y* axis.

The Z axis: the shortest extension of the artifact (the shortest side) determines the positioning of the *Z* axis.

The X axis: the remaining extension of the artifact (the side that is longer than the *Z* but shorter than the *Y*) determines the positioning of the *X* axis.

Once the axis lines are established, the *X*, *Y*, and *Z* faces can be determined. The shapes of these faces determine the overall morphology of a three-dimensional artifact. Six faces are created by the three-dimensionalization of any object, X^1, X^2, Y^1, Y^2, Z^1 and Z^2.

Distinguishing faces follows these simple rules:

First and second faces: First faces are distinguished from second faces solely by relative size: X^2, Y^2 , and Z^2 faces must be larger than X^1, Y^1, and Z^1 faces.

X Faces: X faces are created by the co-occurrence of the *X* axis and the *Y* axis, thus creating a "plan view".

Y Faces: Y faces are created by the co-occurrence of the *Y* axis and the *Z* axis, thus creating a "side view".

Z Faces: Z faces are created by the co-occurrence of the *X* axis and the *Z* axis, thus creating an "end view".

[2] Plane geometry dictates that closed shapes (Euclidean and more complex topological shapes) are determined by the number of sides and degree of angles created by their vertices (Ballard 1970:49). Shapes that contain only interior angles (an angle that is oriented toward the center of the shape) can contain an infinite number of sides. However, the co-occurrence of interior and exterior angles (an angle that is oriented away from the center of the shape) must follow these two rules:

Shapes with 1 exterior angle must have more than 3 sides, and, *shapes with 2 or more exterior angles must have 5 or more sides.*

The number of planes of symmetry present in a shape can be used to distinguish different shapes. Symmetry is determined by the number of sides in a shape and the degree of congruence that exists between the sides. The number of planes of symmetry present in a shape can range from zero to infinity. However, these two rules dictate the occurrence of planes of symmetry for all shapes:

Except for 3 and 5 sided shapes, odd-sided shapes cannot have more than 1 plane of symmetry, and,

for even sided shapes, the number of planes of symmetry are either less than or equal to the number of sides.

[3] Colwell (2003) provides a concise summary of the physics of rotating bodies: when a rigid body is rotated, its resistance to a change in its state of rotation is called its moment of inertia (rotational inertia). This resistance is due to the amount of mass present in the object and the distribution of that mass about the chosen axis of rotation. Different positions of the axis result in different moments of inertia for the same object; the further the mass is distributed from the axis of rotation, the greater the value of its moment of iner-

tia. The rotational inertia for solid spheres can be summarized by the following equation: $I = 2/5\ mr^2$ Where I = inertia, m = mass and r = radius.

The smaller the coefficient of mr^2, the easier it is to accelerate the object. Therefore, spheres accelerate easier than disks and cylinders ($I = ½\ mr^2$), which accelerate easier than thin rings or hoops ($I = mr^2$).

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